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FOURTH SERIES

SUMMARY

SECONDARY RECOVERY OPERATIONS IN PENNSYLVANIA TO JANUARY 1, 1954

Including

PETROLEUM RESERVES AND PRODUCTION BY COUNTIES

BY
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FOREWORD

In conformity with the action of the Executive Committee ef the Interstate Oil Compact Commission taken at Fort Worth, Texas, October 4, 1949, the Commonwealth of Pennsylvania has coöperated with the Interstate Oil Compact Commission in the study of secondary recovery operations in the United States.

The Pennsylvania Bureau of Topographic and Geologic Survey, in coöperation with the Pennsylvania Secondary Recovery Committee of the Secondary Recovery Division of the Interstate Oil Compact Commission, has made a study of the secondary recovery operations in the State by gathering the data included in this publication. Additional information is included to bring up to date the material published in the Bureau's Bulletin M 32 "Crude Oil Reserves of Pennsylvania".

In Pennsylvania there are 76,339 stripper wells producing an average of less than one-half barrel of oil per day. However, these wells have produced over 1,180,000,000 barrels of oil, and perhaps as much as one-half a billion barrels of additional oil may be recovered from these wells by the use of secondary recovery methods of water-flooding and air or gas injection.

Genevieve Blatt

Secretary of Internal Affairs

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To January 1, 1954

Including

PETROLEUM RESERVES AND PRODUCTION BY COUNTIES

By William S. Lytle

INTRODUCTION

This report summarizes information on the secondary recovery projects in Pennsylvania to January 1, 1954 and includes a table listing the secondary recovery projects in operation at the close of 1954. Data on petroleum reserves and county crude oil production is included for the years 1947 to 1953 inclusive. Information contained in this report is intended to supplement Bulletin M32, "Crude Oil Reserves of Pennsylvania".

SECONDARY RECOVERY

The peak year in production by primary methods in Pennsylvania was 1891 (figure 1), when a total of 31,424,000 barrels was produced. This peak was largely due to the flush production of the McDonald field. Following a period of declining production, a secondary peak was attained in 1937, when 19,990,000 barrels of crude oil were produced largely by secondary methods. In 1953 the annual production had declined to 10,930,799 barrels. By January 1, 1954 the Pennsylvania oil fields had produced 1,180,310,000 barrels of crude oil since the discovery of the Drake Well in 1859.

Figure 2 is a map of the Pennsylvania oil fields listing the fields under secondary recovery and showing the type of injection used in each field. Figure 3 shows the general stratigraphic position of the formations under injection and the type of injection used. General information on the projects in each Pennsylvania oil field under secondary

recovery is shown in table 1. A few of the water flood projects listed in this table are "dump" floods.

The Bradford district, consisting of about 100,000 acres, is in the Northern crude oil producing district (figure 4) of Pennsylvania and includes the production of all of the Bradford (14 percent lies in New York), Guffey and Burning Well pools. Over 90 percent of the production from this district comes from the Bradford pool. The Bradford District is currently producing about 45 percent of all the Pennsylvania-grade crude oil. About 556,096,000 barrels had been produced by January 1, 1954 in this district, of which 257,498,000 barrels (figure 5), can be attributed to natural production and 298,608,000 barrels to flood production. The production curve (figure 5), of the Bradford District is a typical production curve of an area under water flood. The estimated natural production curve in figure 5 is an estimate of what the Bradford District would have produced if secondary recovery had never been initiated. The broken line in figure 1 should be considered in the same light.

The total recovery in Pennsylvania by secondary methods at the end of 1953 was 317,208,000 barrels; 300,308,000 barrels were produced by water-flooding and 17,000,000 barrels by air or gas drive. Subtracting this total secondary recovery figure from the total oil produced at the end of the same period leaves 863,102,000 barrels total natural production.

The northern district is producing 85 percent of the present Pennsylvania oil production, while the Middle district is producing 11 percent and the Southern district 4 peroent. Most of the oil fields in the Northern distriot are under seoondary recovery development. A number of fields in the Middle and Southern districts not yet producing under secondary recovery methods should respond favorably to air or gas drive.

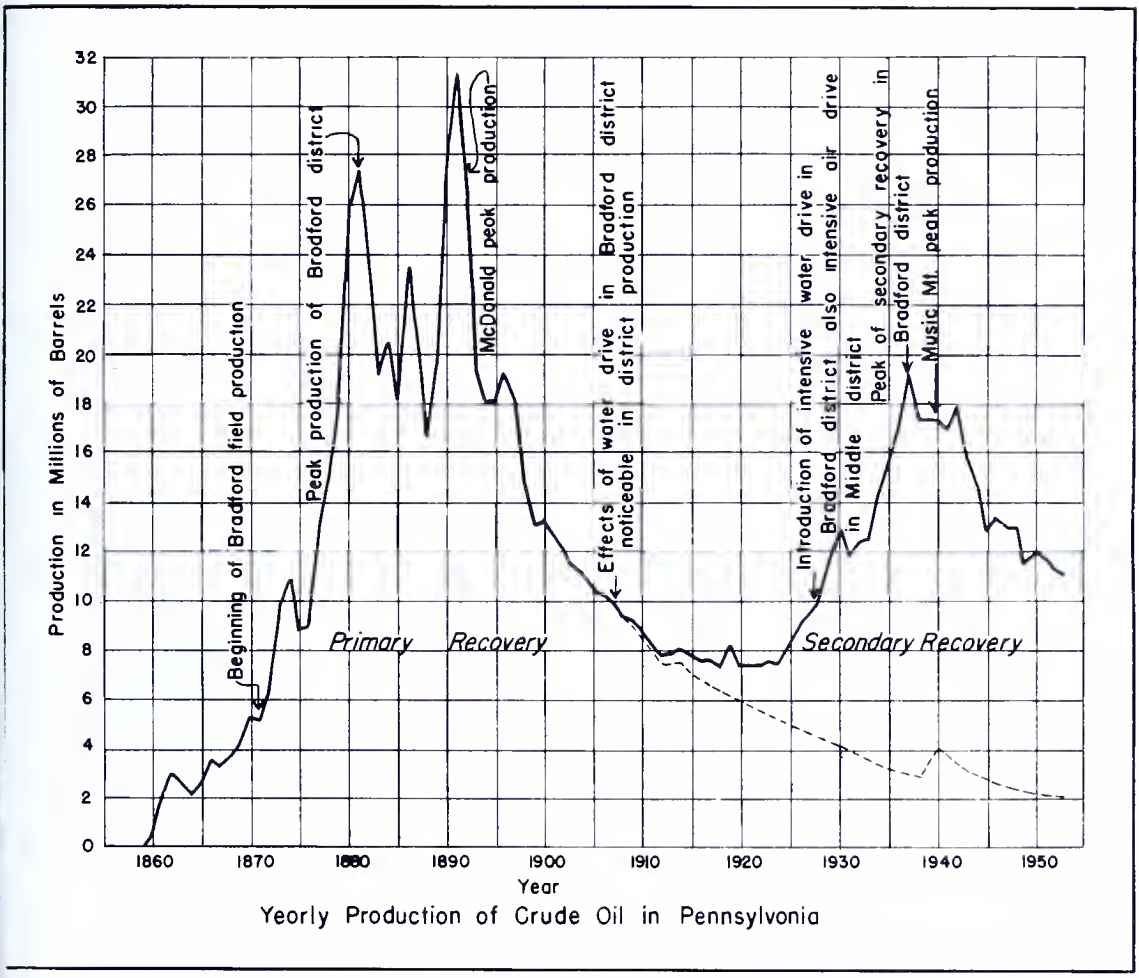


Fig. 1 - Annuol production of crude oil in Pennsylvonio, showing the influence of secondory recovery ond other events upon the production curve

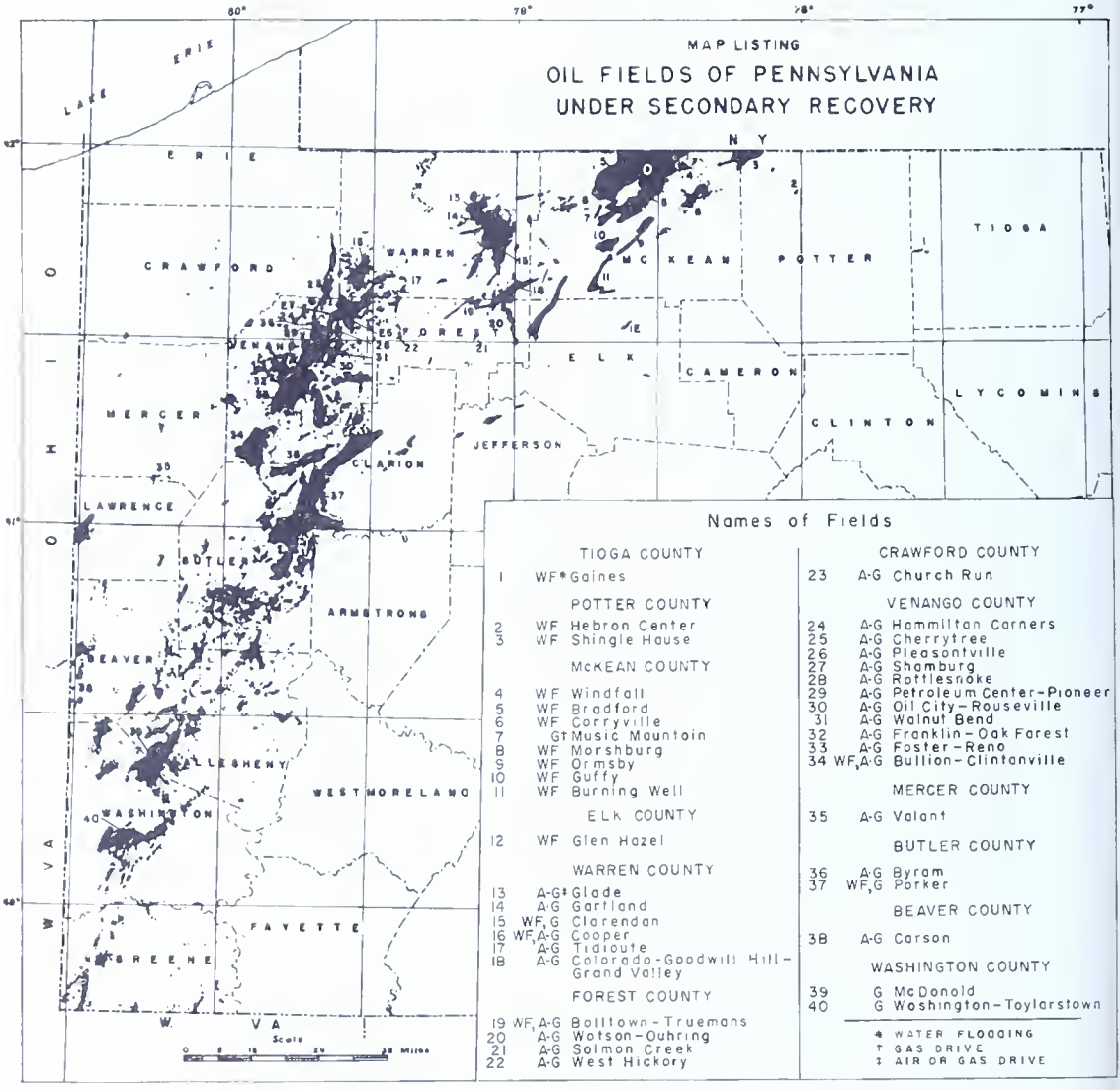
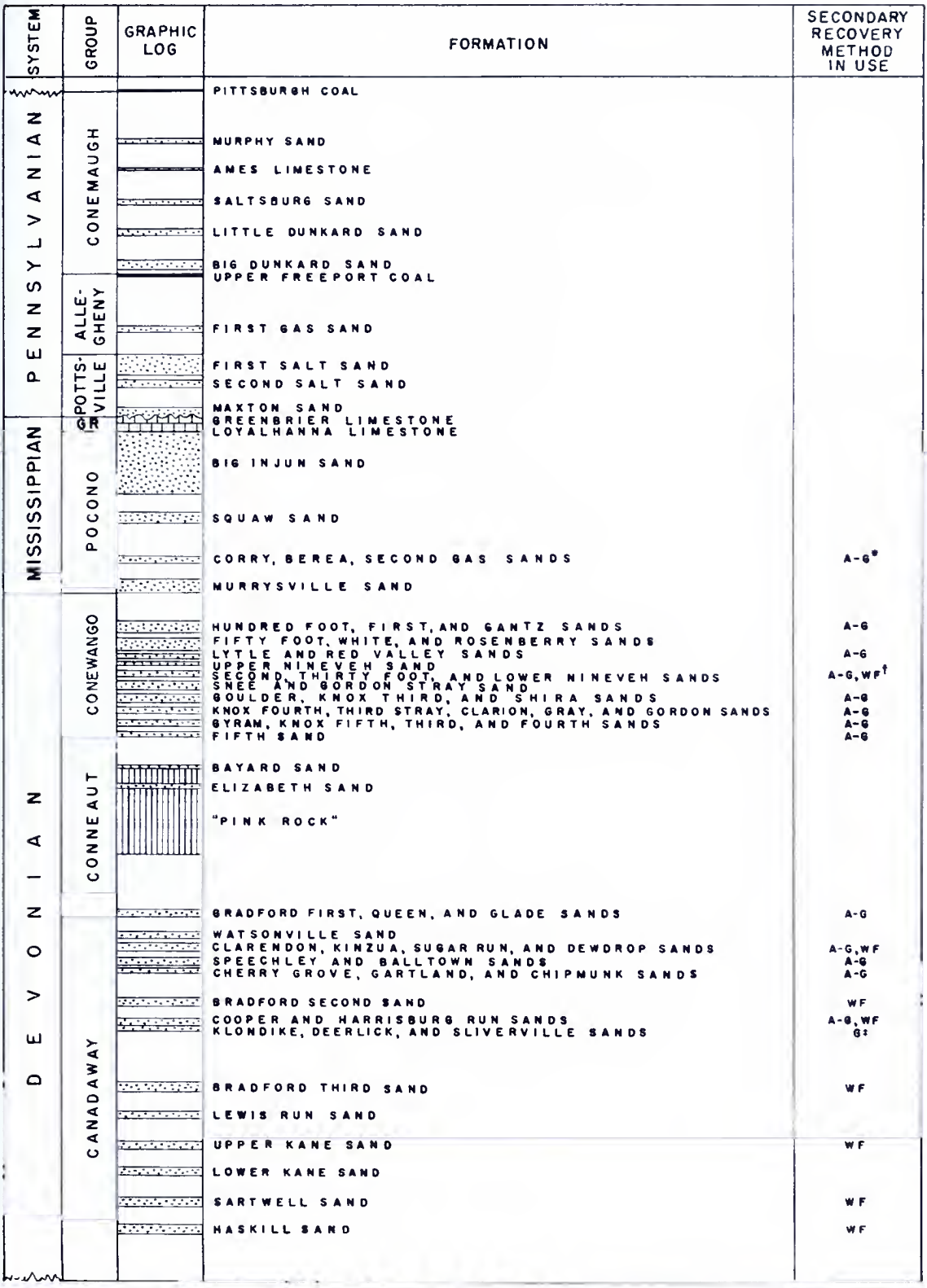

MAP LISTING
OIL FIELDS OF PENNSYLVANIA
UNDER SECONDARY RECOVERY
Names of Fields
TIOGA COUNTY
1 WF* Gaines
POTTER COUNTY
2 WF Hebron Center
3 WF Shingle House
McKEAN COUNTY
4 WF Windfall
5 WF Bradford
6 WF Corryville
7 GT Music Mountain
8 WF Marshburg
9 WF Ormsby
10 WF Guffy
11 WF Burning Well
ELK COUNTY
12 WF Glen Hazel
WARREN COUNTY
13 A-G‡ Glade
14 A-G Garfland
15 WF,G Clarendon
16 WF,A-G Cooper
17 A-G Tidioute
18 A-G Colorado-Goodwill Hill-Grand Valley
FOREST COUNTY
19 WF,A-G Bolltown-Truemans
20 A-G Watson-Ouhring
21 A-G Solmon Creek
22 A-G West Hickory
CRAWFORD COUNTY
23 A-G Church Run
VENANGO COUNTY
24 A-G Hamilton Corners
25 A-G Cherrytree
26 A-G Pleasantville
27 A-G Shamburg
28 A-G Rattlesnake
29 A-G Petroleum Center-Pioneer
30 A-G Oil City-Rouseville
31 A-G Walnut Bend
32 A-G Franklin-Oak Forest
33 A-G Foster-Reno
34 WF,A-G Bullion-Clintonville
MERCER COUNTY
35 A-G Volant
BUTLER COUNTY
36 A-G Byram
37 WF,G Porker
BEAVER COUNTY
38 A-G Carson
WASHINGTON COUNTY
39 G McDonald
40 G Washington-Taylorstown
* WATER FLOODING
† GAS DRIVE
‡ AIR OR GAS DRIVE
ERIE
LAKE
N Y
CRAWFORD
WARREN
McKEAN
POTTER
TIOGA
VENANGO
ELK
CAMERON
LYCOMING
CLINTON
MERCER
JEFFERSON
CLARION
LAWRENCE
BUTLER
ARMSTRONG
BEAVER
ALLEGHENY
WESTMORELAND
WASHINGTON
FAYETTE
GREENE
OHIO
W. VA.
Scale
Miles

Figure 2

Figure 3

Generalized Columnar Section Showing the Oil Bearing Sands Subjected to Air or Gas Drive or Water Flooding in Western Pennsylvania



* AIR OR GAS DRIVE
† WATER FLOODING
‡ GAS DRIVE

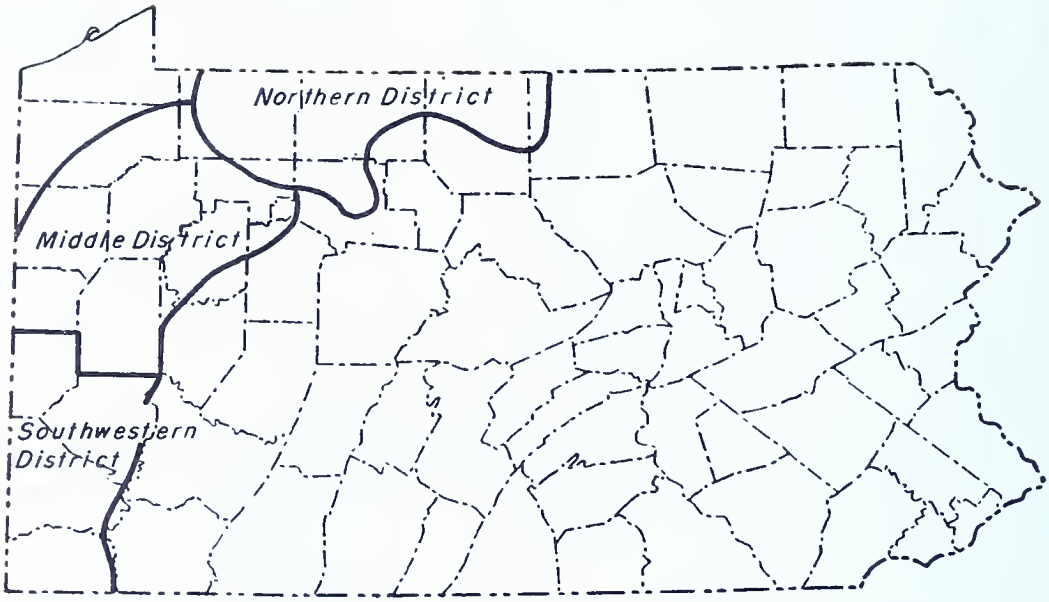


Figure 4. Crude Oil Producing Districts in Pennsylvania

Most of the economically successful water-floods in Pennsylvania are located in the Northern district. An economical flood is operating in the Middle district in the Bullion-Clintonville field where the Second sand is being flooded. The flood pattern is known as a five spot with the producing well generally located in the center of a square and is surrounded by four water intake wells at the corners of the square. The distance between intake and producing wells varies from 225 to 250 feet. An average of 8 to 9 barrels of water is required to produce a barrel of oil, although for some projects an average of up to 25 barrels of water may be used when computing for the entire life of the flood.

The Bradford pool in Pennsylvania covers 72,200 acres. Of this total acreage, 5,760 acres in the pool proper are yet to be developed under secondary methods, 9,560 acres are considered marginal and have

not been subjected to secondary methods and 3,680 acres have been abandoned, leaving 53,200 acres at present under flood. There are 550 water-flood projects in operation in the pool, consisting of 22,700 water input wells and 20,900 producing oil wells.

Air or gas injection is widespread in the Middle district. A reverse seven spot pattern is used where each producing well is located in the center of a triangle and is affected by 3 air or gas input wells located at the three points on the triangle. This pattern is used in intensive operations where spacing is 150 to 250 feet between inputs and producers. Many other patterns are used depending on the location of the producing wells in operation when the project is initiated. The peak year in production by air or gas injection was 1929. A typical production curve of an air or gas drive project is shown in figure 6.

Seventy-nine percent of the state's 1953 production can be attributed to water-flooding, nine percent to air or gas injection, and 12 percent to natural production, some of which is being produced under vacuum. The petroleum industry in Pennsylvania is operating 103,886 wells. 27,547 are input wells in secondary recovery projects and 76,339 are producing oil wells. There are 25,362 input wells and 23,545 oil wells associated with water-flood projects. 2,185 input wells and 7,740 oil wells are operating in air or gas injection projects. The remaining 45,054 wells are oil producers, either natural or under vacuum.

PETROLEUM PRODUCTION AND RESERVES

The crude oil production history of the major oil producing counties in Pennsylvania are shown in figures 7a, 7b, 7c, 8 and 9. The affect of secondary recovery on the county production curves is very noticeable for Crawford, McKean, Potter and Warren counties. Pennsylvania production is

TABLE 1.

SECONDARY RECOVERY PROJECTS OPERATING IN PENNSYLVANIA AT CLOSE OF 1954

Map No.	Field	County	Number of Projects	Number Injection Wells	Number Producing Wells	Acres Subjected Injection	Name of Formation	Depth Top of Pay-ft.
1.	Gaines	Tioga	1	8 W†	7	25	*Atwell	775
2.	Hebron Center	Potter	1	40 W	48	100	Bradford Third	1 395
3.	Shingle House	McKean and Potter	10	331 W	318	766	Bradford Third	1 165
4.	Windfall	McKean	3	122 W	107	280	Bradford Third	1 300
5.	Bradford	McKean	550	22 700 W	20 900	53 200	Bradford Third	1 400
6.	Coryville	McKean	2	117 W	125	255	Haskill	1 900
7.	Music Mountain	McKean	4	64 G‡	229	390	Sliverville	1 500
8.	Marshburg	McKean	1	13 W	9	42	Bradford Second	1 300
9.	Ormsby	McKean	1	18 W	30	100	Bradford Third	2 150
			1	31 W	25	111	Upper Kane	2 250
10.	Guffy	McKean	4	719 W	755	2 315	Bradford Third	1 650
11.	Burning Well	McKean	2	619 W	650	1 885 300	Bradford Third Upper Kane	1 400 1 600
12.	Glen Hazel	Elk	1	53 W	52	118	Bradford Third	1 950
13.	Glade	Warren	1	2A-G×	5	25	Glade	900
14.	Gartland	Warren	1	1A-G	8	10	Gartland	1 200
15.	Clarendon	Warren	15	533 W	434	1 280	Clarendon	1 190
			2	12A-G	130	112	Clarendon	1 190

SECONDARY RECOVERY PROJECTS OPERATING IN PENNSYLVANIA AT CLOSE OF 1954

Table 1 (2)

Map No.	Field	County	Number of Projects	Number Injection Wells	Number Producing Wells	Acres Subjected Injection	Name of Formation	Depth Top of Pay-ft.
16.	Cooper	Warren	1	2 W	15	10	Balltown	1 400
			1	2A-G	16	30	Balltown	1 400
			2	23A-G	57	155	Cooper	1 650
17.	Tidioute	Warren	2	46A-G	207	426	First	450
			1	40A-G	170	500	Red Valley	550
			1	7A-G	40	100	Second	600
			6	166A-G	533	1 635	Third	700
			1	7A-G	36	200	First Third	450 750
			1	15A-G	170	600	Second Third	600 700
			1	6A-G	25	50	Queen	1 150
18.	Colorado-Goodwill Hill Grand Valley	Warren	3	311A-G	903	1 913	First Third	375 675
			4	310A-G	786	3 284	Third	700
19.	Balltown-Truemans	Forest	1	2 W	6	25	Balltown	1 500
			1	3A-G	10	50	Balltown	1 500
20.	Watson-Duhring	Forest	1	1A-G	4	20	Balltown	1 700

SECONDARY RECOVERY PROJECTS OPERATING IN PENNSYLVANIA AT CLOSE OF 1954

Table 1 (3)

Map No.	Field	County	Number of Projects	Number Injection Wells	Number Producing Wells	Acres Subjected Injection	Name of Formation	Depth Top of Pay-ft.
21.	Salmon Creek	Forest	1	4A-G	15	90	Knox Third	800
22	West Hickory	Forest	3	23A-G	55	90	Red Valley	700
			1	11A-G	70	350	Third Stray	650
23.	Church Run	Crawford	10	98A-G	402	641	Third	575
24.	Hamilton Corners	Venango	1	9A-G	60	75	First	500
25.	Cherrytree	Venango	1	3A-G	23	40	First	650
26.	Pleasantville	Venango	1	11A-G	54	90	First	600
			10	237A-G	922	1 331	Red Valley	600
			1	14A-G	38	100	Second	650
			1	79A-G	191	600	Red Valley Third	600 750
			1	89A-G	217	822	First Second Third	450 650 750
27.	Shamburg	Venango	3	17A-G	78	105	Third	650
28.	Rattlesnake	Venango	1	5A-G	24	75	First	600

SECONDARY RECOVERY PROJECTS OPERATING IN PENNSYLVANIA AT CLOSE OF 1954

Table 1 (4)

Map No.	Field	County	Number of Projects	Number Injection Wells	Number Producing Wells	Acres Subjected Injection	Name of Formation	Depth Top of Pay-ft.
29.	Petroleum Center-Pioneer	Venango	1	86A-G	278	800	First Second Third	420 600 720
			1	10A-G	60	75	Second	600
30.	Oil City-Rouseville	Venango	2	14A-G	47	75	First	450
			1	84A-G	517	1 003	Second	600
			1	2A-G	11	15	Third	750
			1	13A-G	49	80	First Second	450 630
			2	23A-G	48	75	Second Third	600 730
			1	19A-G	50	65	First Second Third	450 630 750
31.	Walnut Bend	Venango	1	6A-G	20	50	Red Valley	500
32.	Franklin Oak forest	Venango	1	1A-G	15	10	First	550
			1	20A-G	158	400	Second	725
33.	Foster-Reno	Venango	7	164A-G	692	1 687	Second	750
			9	67A-G	193	267	Second Third	750 875

SECONDARY RECOVERY PROJECTS OPERATING IN PENNSYLVANIA AT CLOSE OF 1954

Table 1 (5)

Map No.	Field	County	Number of Projects	Number Injection Wells	Number Producing Wells	Acres Subjected Injection	Name of Formation	Depth Top of Pay-ft.
34.	Bullion-Clintonville	Venango	4	47 W	58	196	Second	1 050
			1	1A-G	12	10	Second Third	1 050 1 175
			1	6A-G	9	30	Third	1 175
35.	Volant	Mercer	1	5A-G	30	120	First	750
36.	Byram	Butler	1	2A-G	4	10	Second Third	1 150 1 280
37.	Parker	Butler	1	7 W	6	12	Knox Third	1 100
			1	3A-G	10	15	Knox Third	1 100
38.	Carson	Beaver	2	5A-G	21	65	Berea	1 300
39.	McDonald	Washington and Allegheny	1	12A-G	125	3 200	Gordon Fourth	2 186 2 250
40.	Washington Taylorstown	Washington	1	26A-G	255	5 000	Gordon	2 525
	Total		705	27 547	31 285	87 981		

* This sand occurs in strata of Upper Devonian age about 700 feet below the lowest red beds of the Catskill facies.
† Water injection.
‡ Gas injection.
× Air or gas injection.

TABLE 2.

WELLS AND CRUDE OIL PRODUCTION IN PENNSYLVANIA BY COUNTIES

County	1947		1948		1949		1950	
	Number of[1] producing oil wells	Crude oil[1] production (bbls.)	Number of[1] producing oil wells	Crude oil[1] production (bbls.)	Number of[1] producing oil wells	Crude oil[1] production (bbls.)	Number of[1] producing oil wells	Crude oil[1] production (bbls.)
Allegheny	982	186 747	878	181 135	827	173 346	784	155 430
Armstrong	247	16 453	245	15 316	248	16 455	245	16 483
Beaver	339	18 146	327	19 393	296	18 719	257	15 676
Butler	4 090	267 615	3 929	256 818	3 696	242 450	3 634	233 568
Clarion	1 907	69 605	1 838	65 422	1 735	69 521	1 724	64 773
Crawford	1 091	41 908	1 096	46 032	1 047	45 073	1 058	35 520
Elk	701	38 496	711	35 121	711	61 233	676	37 130
Forest	1 272	69 347	1 240	37 602	1 160	67 383	1 158	65 401
Greene	629	101 021	591	95 076	570	79 153	564	69 726
Jefferson	103	4 907	105	6 070	104	6 300	106	5 640
McKean	36 130	10 762 322	36 142	10 689 895	36 652	9 367 546	36 558	9 952 525
Mercer	247	7 238	247	7 163	244	6 942	248	6 869
Potter	256	40 592	303	46 726	313	42 905	304	125 561
Tioga	50	2 750	50	3 093	50	3 412	50	2 432
Venango	22 435	664 473	21 791	627 955	21 296	642 845	21 025	551 719
Warren	9 287	391 007	9 500	506 849	9 449	486 453	9 369	447 701
Washington	1 422	293 266	1 264	270 141	1 217	239 423	1 216	221 366
Total	81 188	12 975 893	80 257	12 909 807	79 615	11 569 160	78 976	12 007 520

WELLS AND CRUDE OIL PRODUCTION IN PENNSYLVANIA BY COUNTIES

County	1951		1952		1953		
	Number of[1] producing oil wells	Crude oil[1] production (bbls.)	Number of[1] producing oil wells	Crude oil[1] production (bbls.)	Number of[1] producing oil wells	Crude oil[1] production (bbls.)	Total crude oil production 1947 to 1953 inclusive (bbls.)
Allegheny	734	150 169	1 209	147 831	653	159 622	1 154 280
Armstrong	243	15 643	374	15 752	239	15 138	111 240
Beaver	257	16 322	417	14 640	242	14 397	117 293
Butler	3 539	235 765	3 445	216 871	3 293	215 572	1 668 659
Clarion	1 703	63 091	1 669	63 601	1 608	59 291	455 304
Crawford	910	37 886	916	35 295	848	39 383	281 097
Elk	668	24 146	673	31 569	658	32 097	259 792
Fayette	6	752	12	788	6	735	2 275
Forest	1 160	59 047	1 160	48 825	1 157	72 908	420 513
Greene	502	67 669	851	65 626	445	62 893	541 164
Jefferson	106	5 831	106	5 712	107	5 660	40 120
McKean	36 064	9 404 768	36 031	9 057 674	36 172	8 742 008	67 976 738
Mercer	248	6 341	246	6 652	241	5 796	47 001
Potter	371	219 543	403	223 335	383	211 488	910 150
Tioga	18	2 750	18	3 296	16	2 748	20 481
Venango	19 448	672 919	21 285	607 268	19 698	599 422	4 366 601
Warren	9 762	499 204	9 727	476 021	9 488	475 139	3 282 374
Washington	1 168	218 572	2 079	212 774	1 085	216 502	1 672 044
Total	76 907	11 700 419	80 621	11 233 530	76 339	10 930 799	83 327 126

1. Data from Report on Productive Industries, Public Utilities and Miscellaneous Statistics by Pa. Dept. of Int. Affairs. See: Lytle, William S., 1950, Crude Oil Reserves of Pennsylvania, Pa. Geol. Survey, 4th Ser., Bull. M32 for statistics from 1859 to 1946 inclusive.

TABLE 3.

SUMMARY OF COUNTY OIL RESERVES AS OF JANUARY 1, 1954

County	Acres	Total Oil in place (bbls.)	Proved Recoverable[1] by Primary plus Secondary methods (bbls.)	Probably[2] Recoverable by Secondary methods (bbls.)	Possibly[3] Recoverable by Secondary methods (bbls.)
Allegheny	44 722	78 242 000	2 762 000	15 901 000	23 949 000
Armstrong	11 432	31 473 000	681 000	7 786 000	7 786 000
Beaver	13 407	27 763 000	436 000	4 894 000	5 297 000
Butler	103 026	281 522 000	13 525 000	50 584 000	90 294 000
Clarion	22 910	76 482 000	6 802 000	14 482 000	37 519 000
Crawford	8 360	54 005 000	3 542 000	7 679 000	19 919 000
Elk	6 160	26 060 000	640 000	2 044 000	2 340 000
Forest	16 277	64 578 000	5 374 000	11 655 000	29 957 000
Greene	13 261	19 897 000	940 000	4 249 000	4 561 000
Jefferson	1 534	3 140 000	111 000	470 000	1 232 000
Lawrence	8 350	16 700 000	100 000	1 000 000	1 000 000
McKean	101 775	826 611 000	91 858 000	122 830 000	162 830 000
Mercer	4 500	7 072 000	422 000	932 000	2 462 000
Potter	4 420	30 710 000	2 590 000	4 490 000	6 090 000
Tioga	450	2 170 000	15 000	25 000	35 000
Venango	155 819	725 443 000	51 928 000	113 226 000	288 287 000
Warren	63 777	292 365 000	25 988 000	47 755 000	83 771 000
Washington	45 013	86 877 000	5 921 000	18 184 000	37 722 000
Total	625 193	2 651 110 000	213 635 000	428 186 000	805 051 000

1. Reserve figures as published by Lytle, William S., 1950, Crude Oil Reserves of Pennsylvania, Pa. Geol. Survey, 4th Ser., Bull. M32, have been increased by 1,000,000 barrels for Greene County, 100,000 barrels for Jefferson County, 72,377,000 barrels for McKean County and 20,000 barrels for Tioga County.

2. Reserve figures increased by 62,000,000 barrels for McKean County and 30,000 barrels for Tioga County.

3. Reserve figures increased by 40,000,000 barrels for McKean County and 40,000 barrels for Tioga County.

continuing to decline, but most of the oil fields would have been abandoned years ago if secondary recovery hadn't been initiated. Table 2 shows the number of producing oil wells and the crude oil produced by counties for 1947 to 1953 inclusive, as reported by the Pennsylvania Bureau of Statistics.

The total oil in place in the Pennsylvania oil fields as of January 1, 1954, was 2,651,110,000 barrels. This and other information is shown in table 3. The proved recoverable reserve by primary plus secondary methods, for the areas now operating under secondary recovery methods, is estimated at 110,892,000 barrels as of January 1, 1954. Other areas are considered amenable to secondary recovery methods, thus increasing the proven reserve to 213,635,000 barrels as of January 1, 1954.

ACKNOWLEDGEMENTS

In connection with the preparation of this summary, the writer is grateful for the contributions made by the many oil producers. Miss Lillian Heeren of the Survey staff did the drafting of the illustrations.

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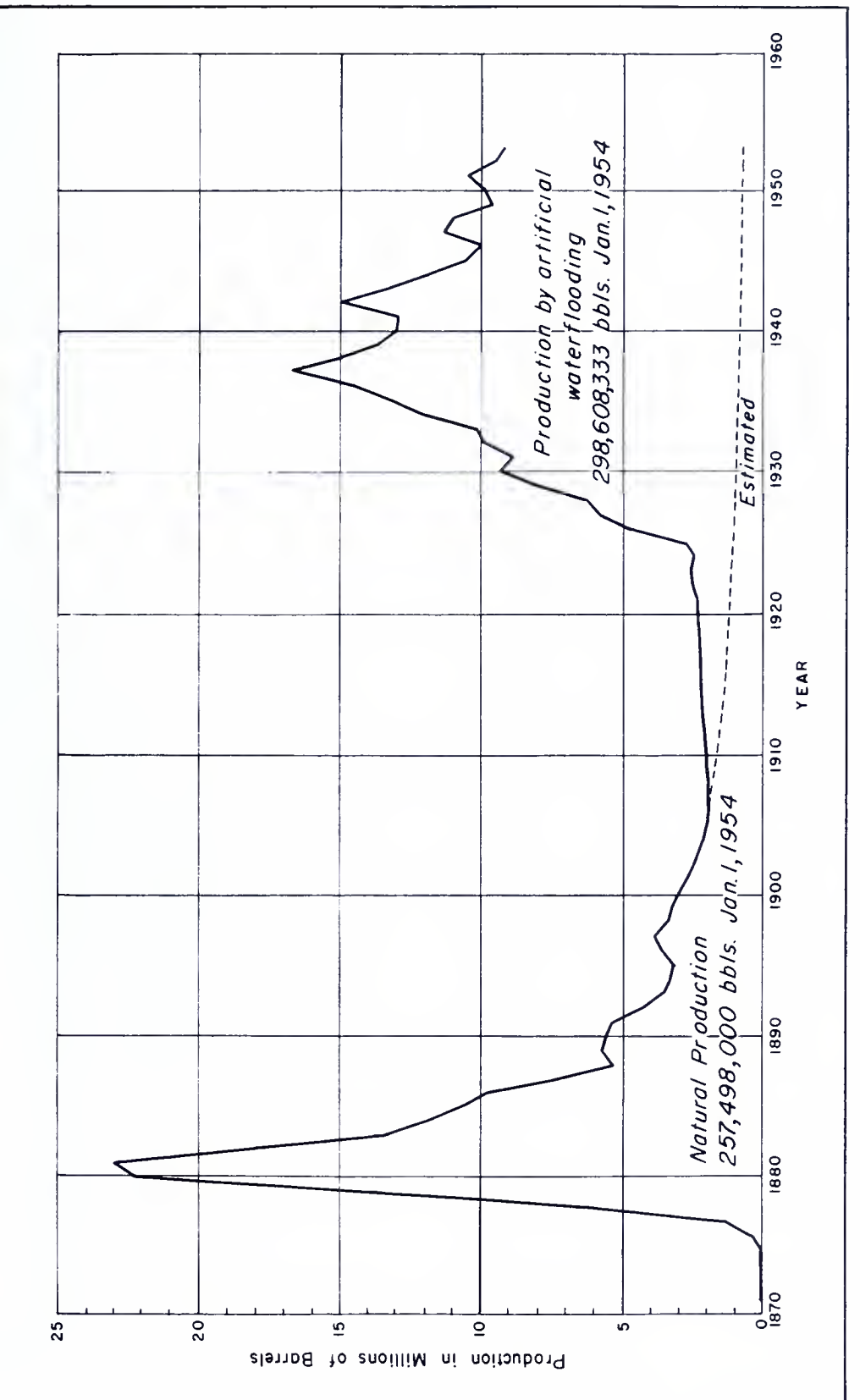

Fig. 5. Crude oil production curve of the Bradford district, Pa. & N.Y.
Music Mt. field excluded

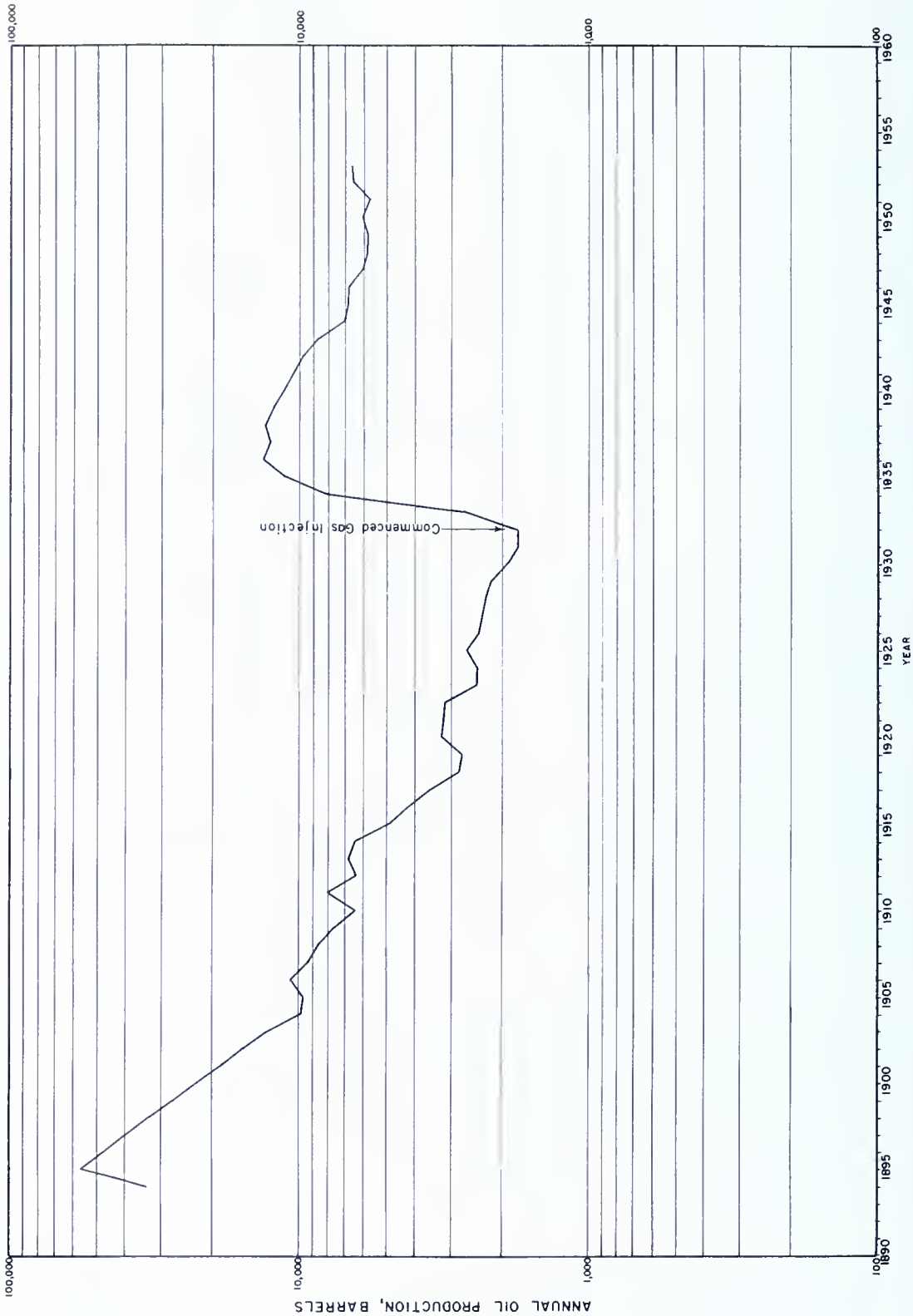

Fig. 6 Production history of Wallace Heirs lease, McDonald field

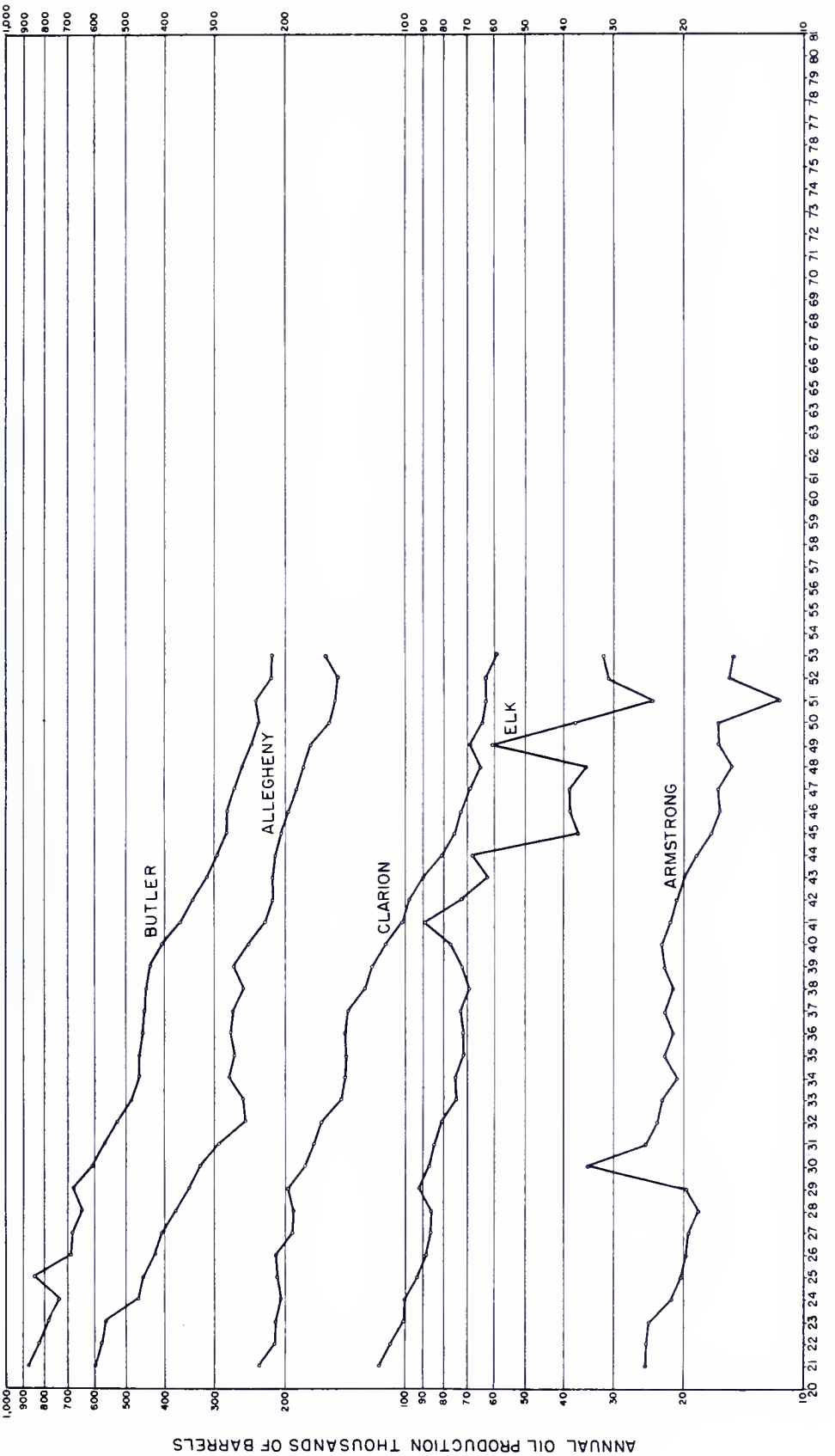

Fig. 7a ANNUAL OIL PRODUCTION IN PENNSYLVANIA BY COUNTIES

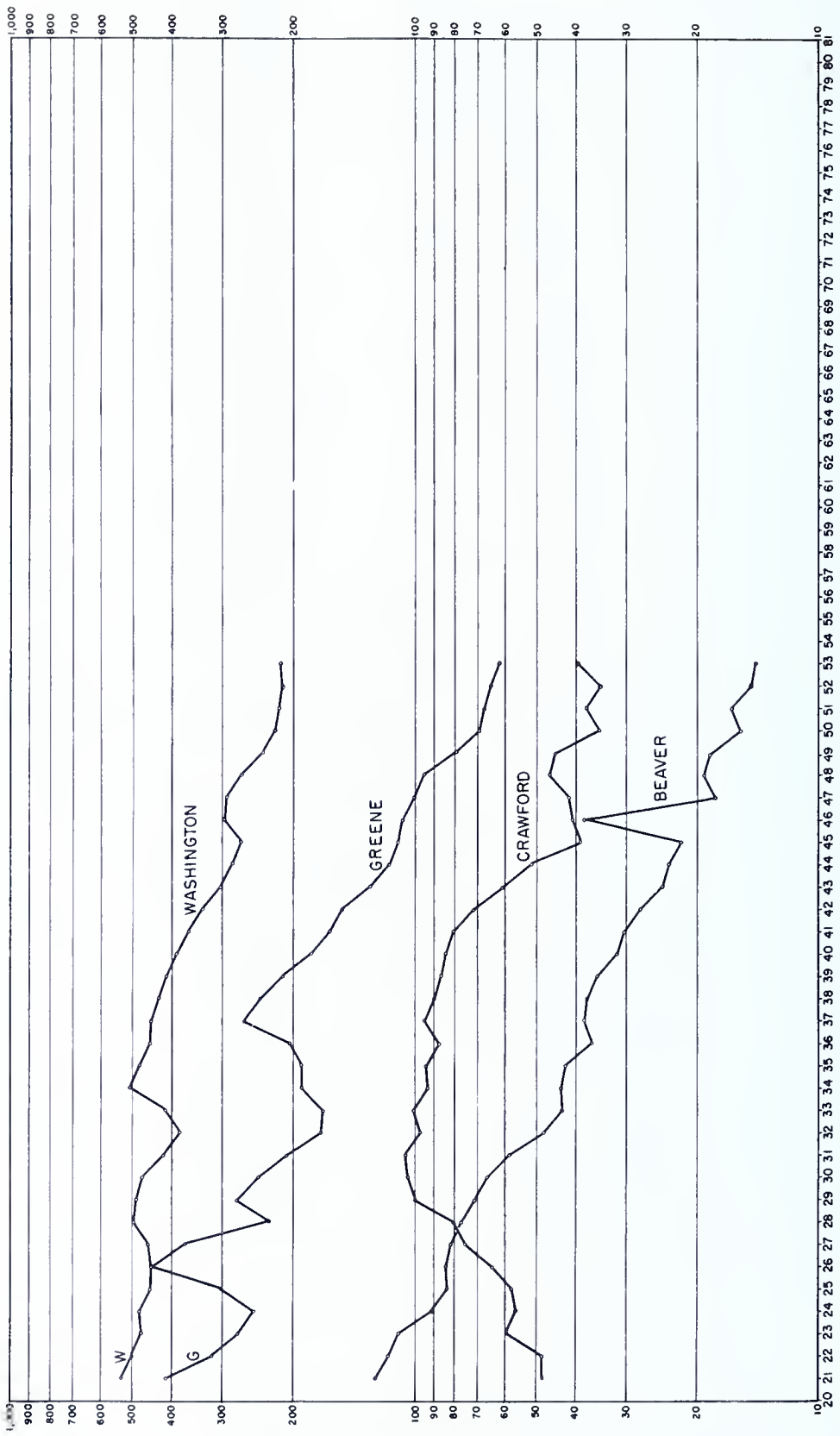

Fig. 7b ANNUAL OIL PRODUCTION IN PENNSYLVANIA BY COUNTIES

Fig. 7c ANNUAL OIL PRODUCTION IN PENNSYLVANIA BY COUNTIES

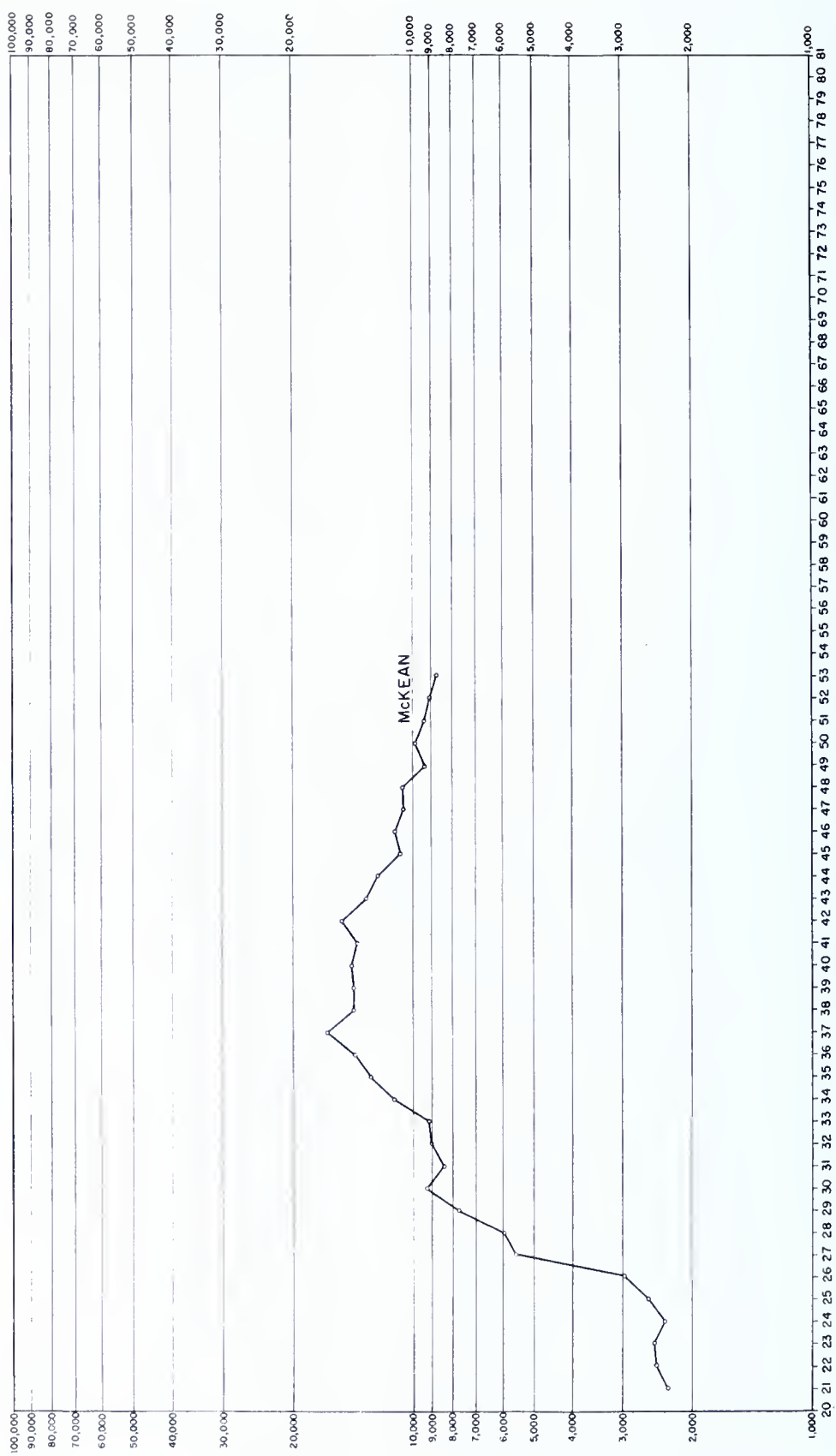

Fig. 8 ANNUAL OIL PRODUCTION McKEAN COUNTY, PENNSYLVANIA

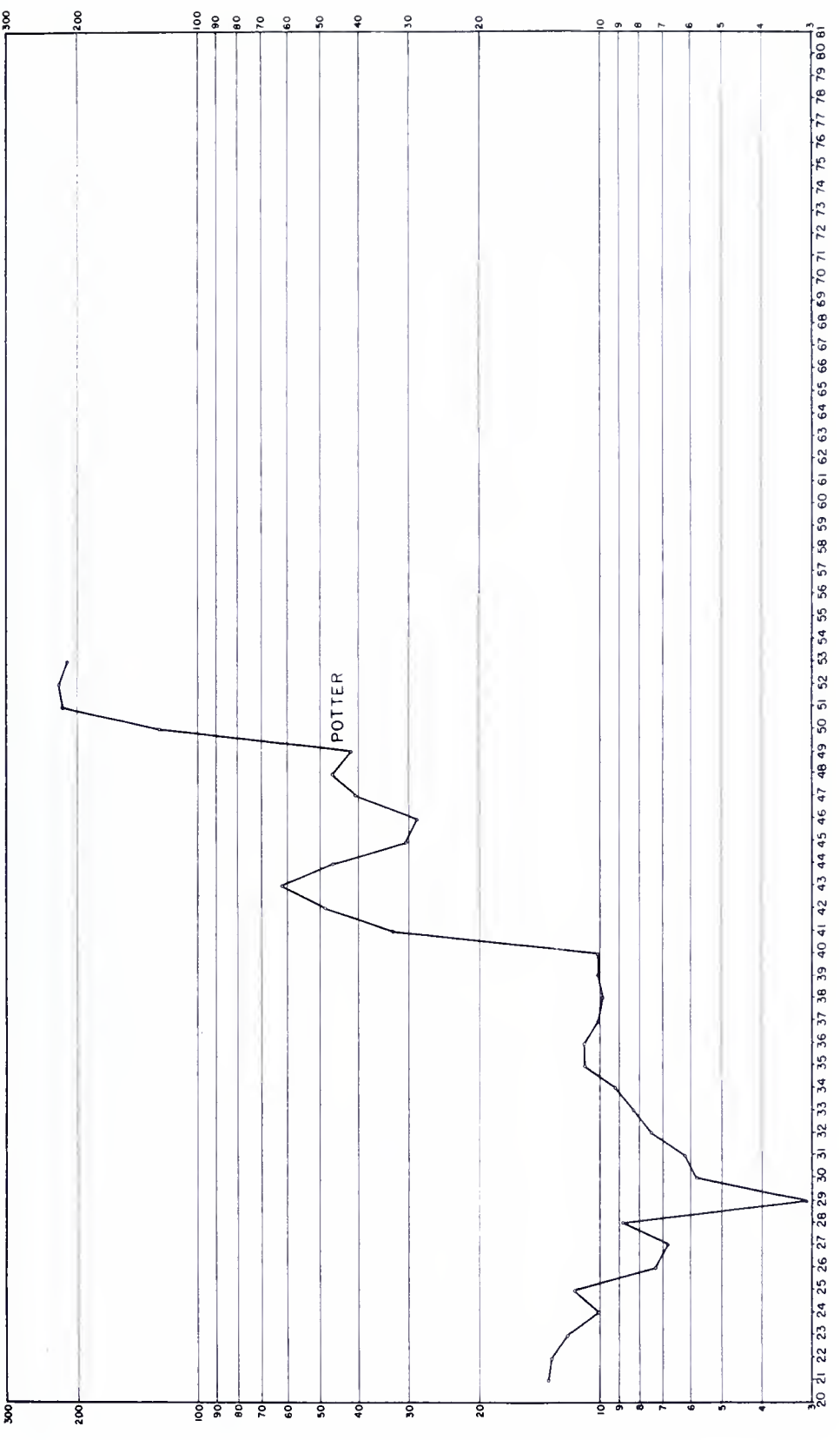

Fig. 9 ANNUAL OIL PRODUCTION POTTER COUNTY, PENNSYLVANIA